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Advances in In-Pavement Lighting Technology

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SIEMENS

Overview

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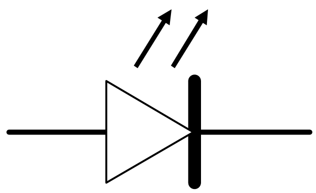
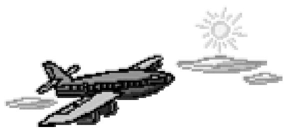
- ICAO/FAA Specifications
- About LEDs
- New LED Light
- Benefits
- Installation
- Electrical Design
- Technical Issues
- Future



Introduction

- Intensity levels of LEDs have increased to the point that it is becoming more and more practical to use them in airfield lighting applications
- This presentation will explore application and installation issues associated with using LEDs on the airfield, especially for in-pavement lights



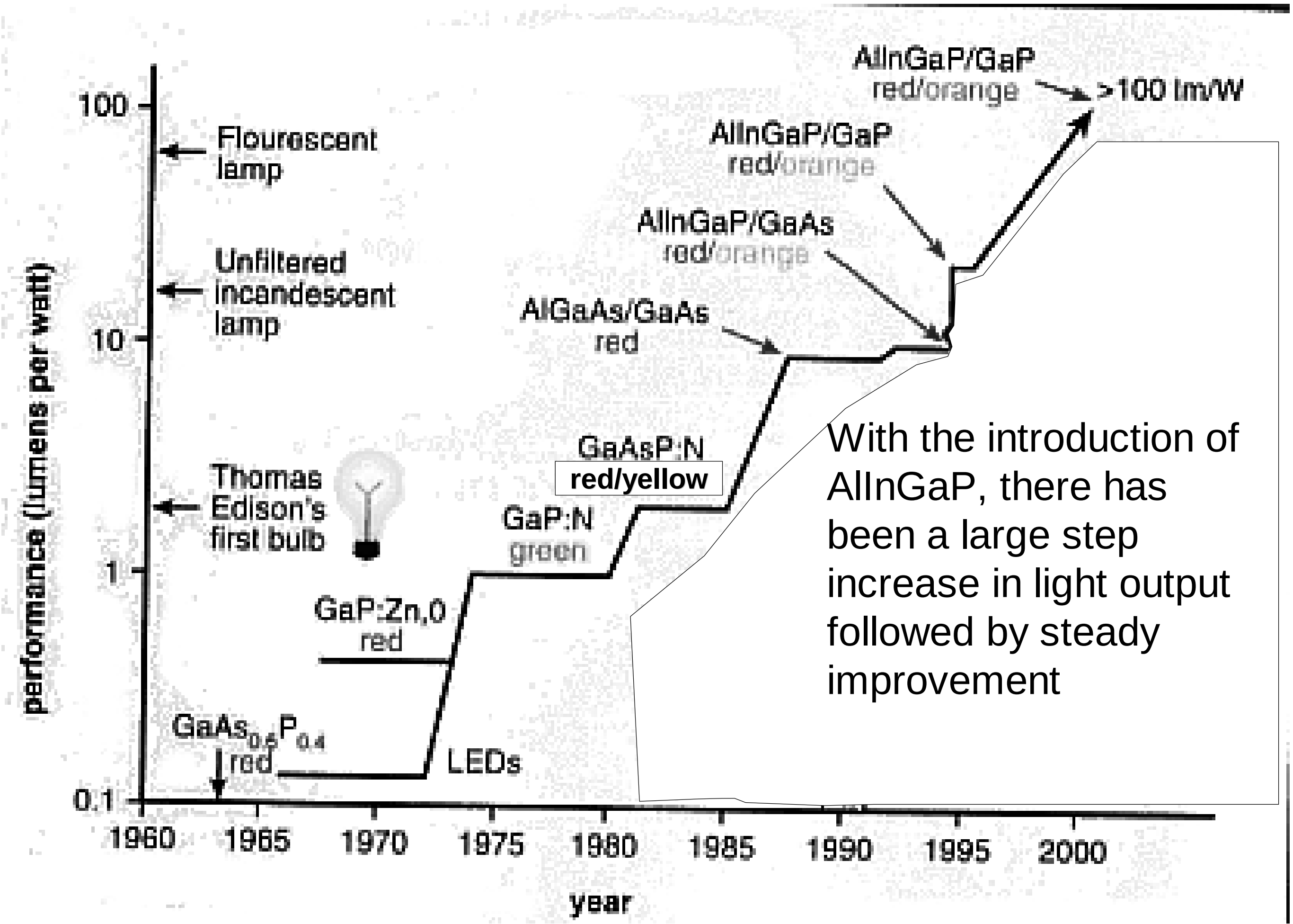
FAA/ICAO Specifications

- FAA
  - Issued "Performance Requirements for LED Lighting"
  - Appropriate Advisory Circulars are supposed to be updated at a future date
- ICAO
  - Annex 14, Section 5 – 3
  - Functional requirements, not specific to LEDs

About LEDs

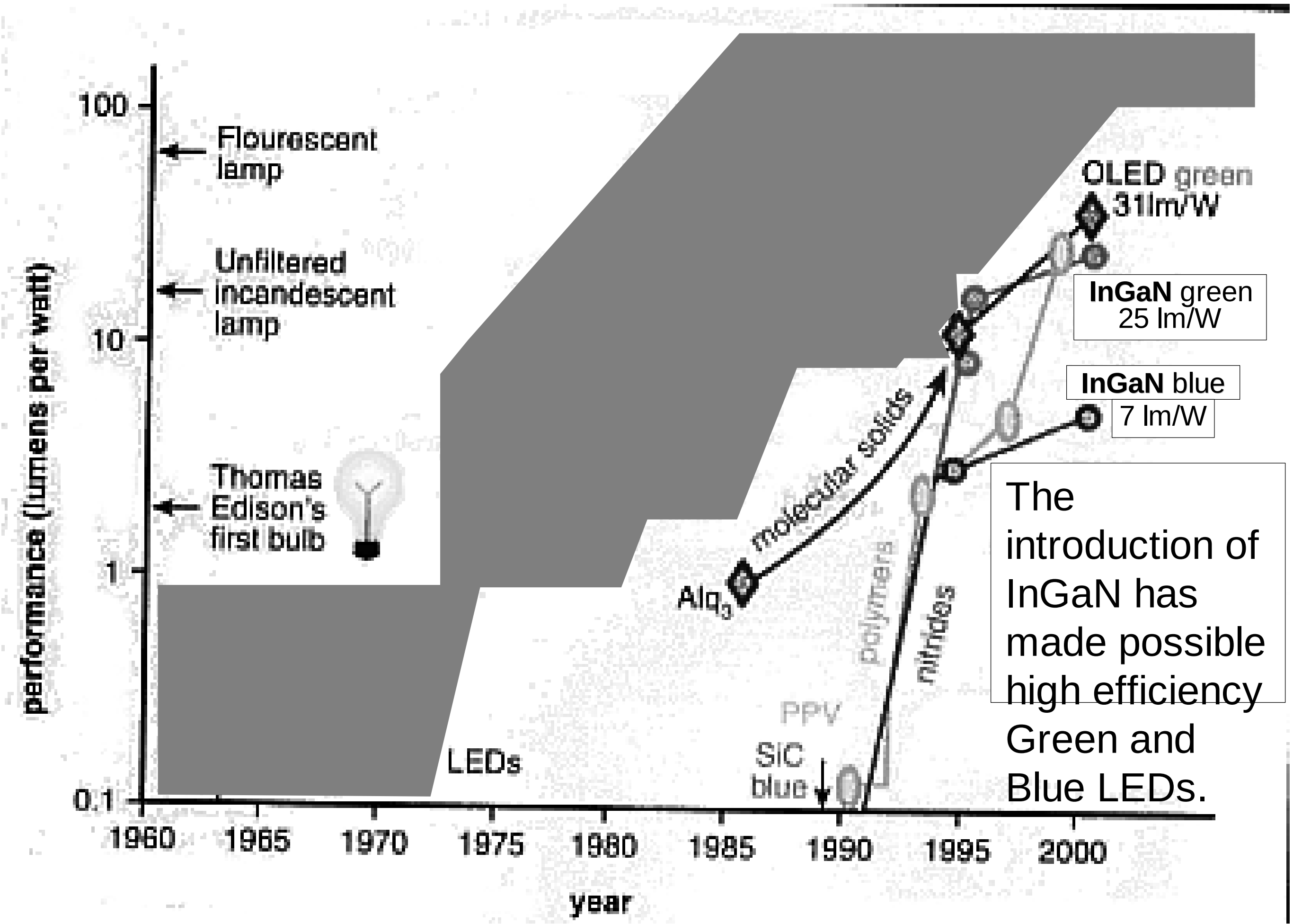
- LEDs are high efficiency light sources that provide colored light without any filter loss
- LED colors are Red, Yellow, Green and Blue
  - White is possible using a combination of colored LEDs
- LEDs are made from different materials which effect color, intensity, efficiency
  - Aluminum indium gallium phosphide (AlInGaP) produce red and amber
  - Indium gallium nitride (InGaN) produce green and blue

History of LED efficiency



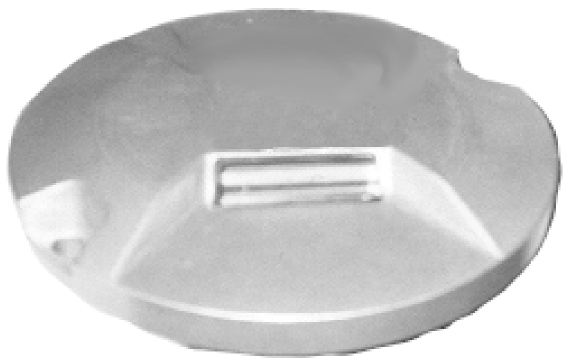
With the introduction of AlInGaP, there has been a large step increase in light output followed by steady improvement

History of LED efficiency

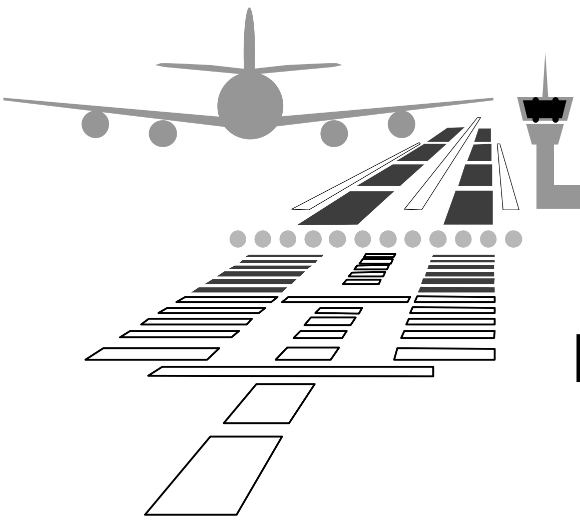


The introduction of InGaN has made possible high efficiency Green and Blue LEDs.

New In-pavement Light



- Meets ICAO ANNEX 14 in Red, Green or Yellow
- Other versions meet L-852A through D (not shown)
- Can plug directly into 3 or 5-step, 6.6A series circuit
- 20W
- Long life- *56,000* hours
- Aluminum fixture (Similar quality to existing aluminum types)
- Available in 8” or 12”

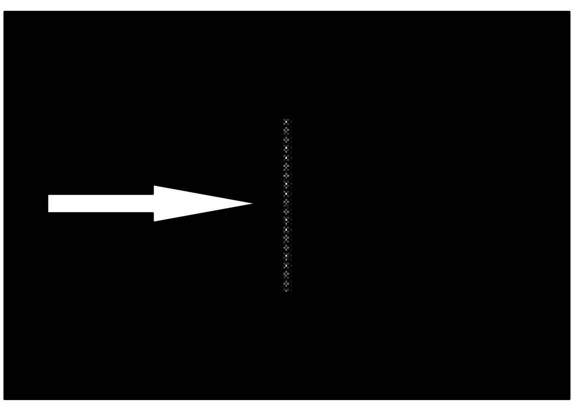


Advances in In-pavement Technology

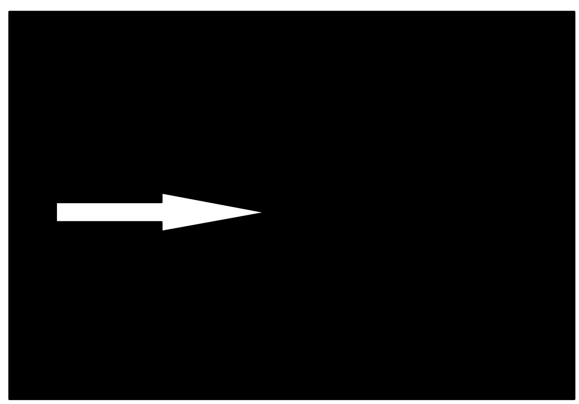
Benefits

Lamp Filters

- Filters are used with lamps to generate colors and light is lost as a result
- Absorption- Converts unwanted light to heat
- Dichroic- Reflects unwanted light



Absorption

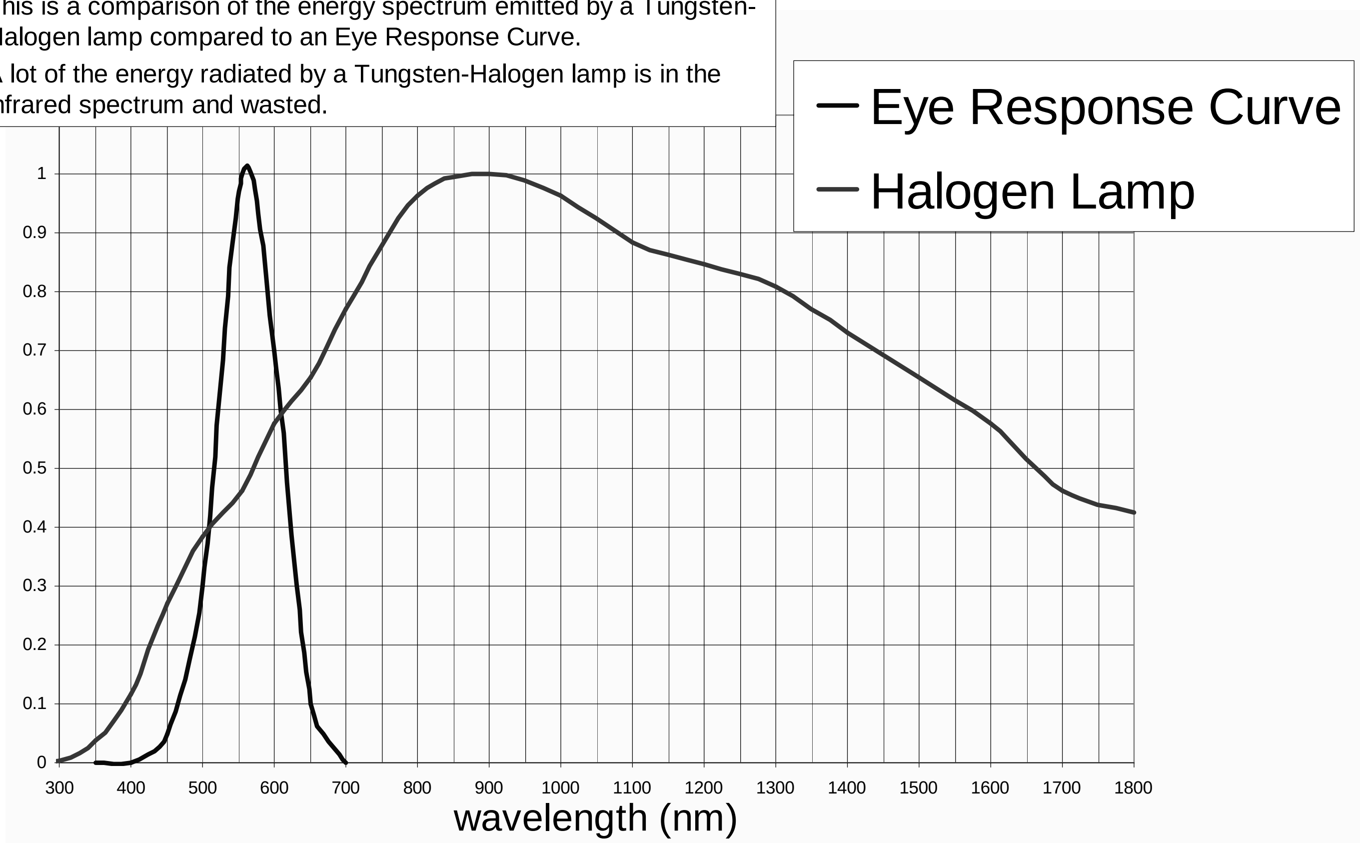


Dichroic

Halogen Lamp Light Spectrum

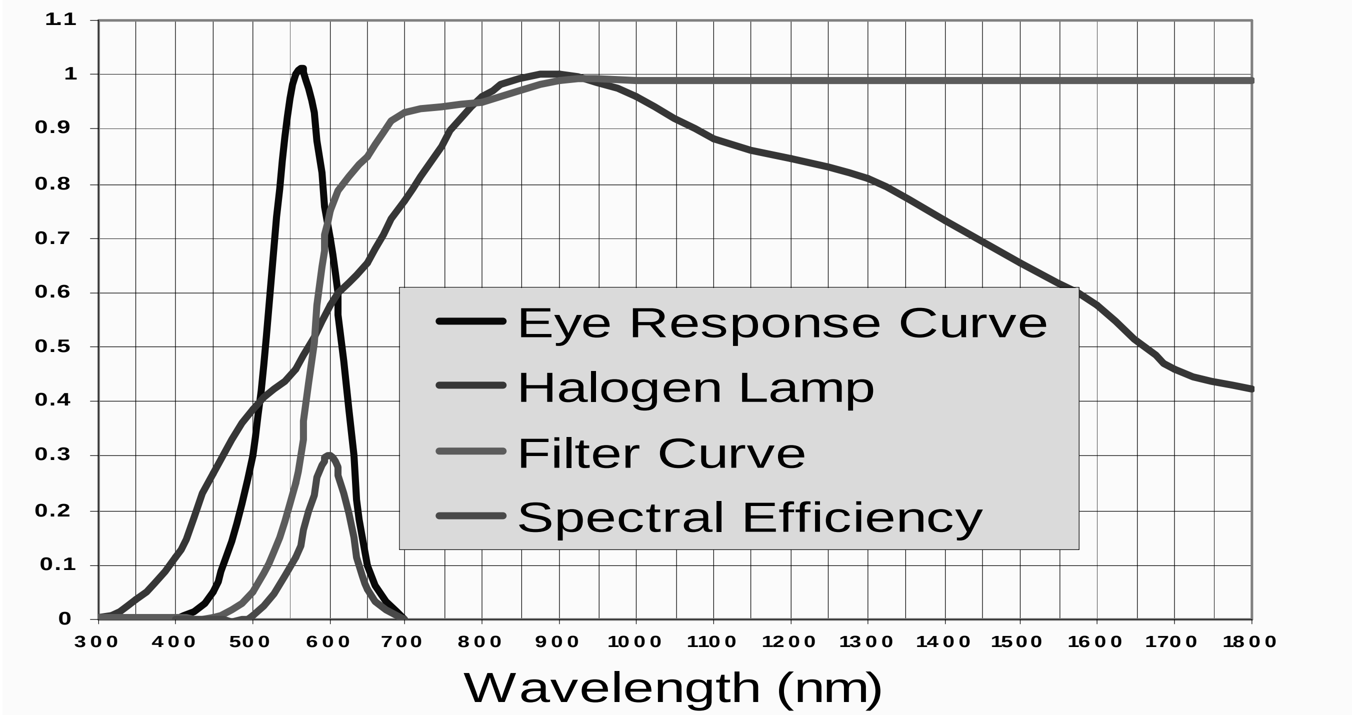
This is a comparison of the energy spectrum emitted by a Tungsten-Halogen lamp compared to an Eye Response Curve.

A lot of the energy radiated by a Tungsten-Halogen lamp is in the infrared spectrum and wasted.



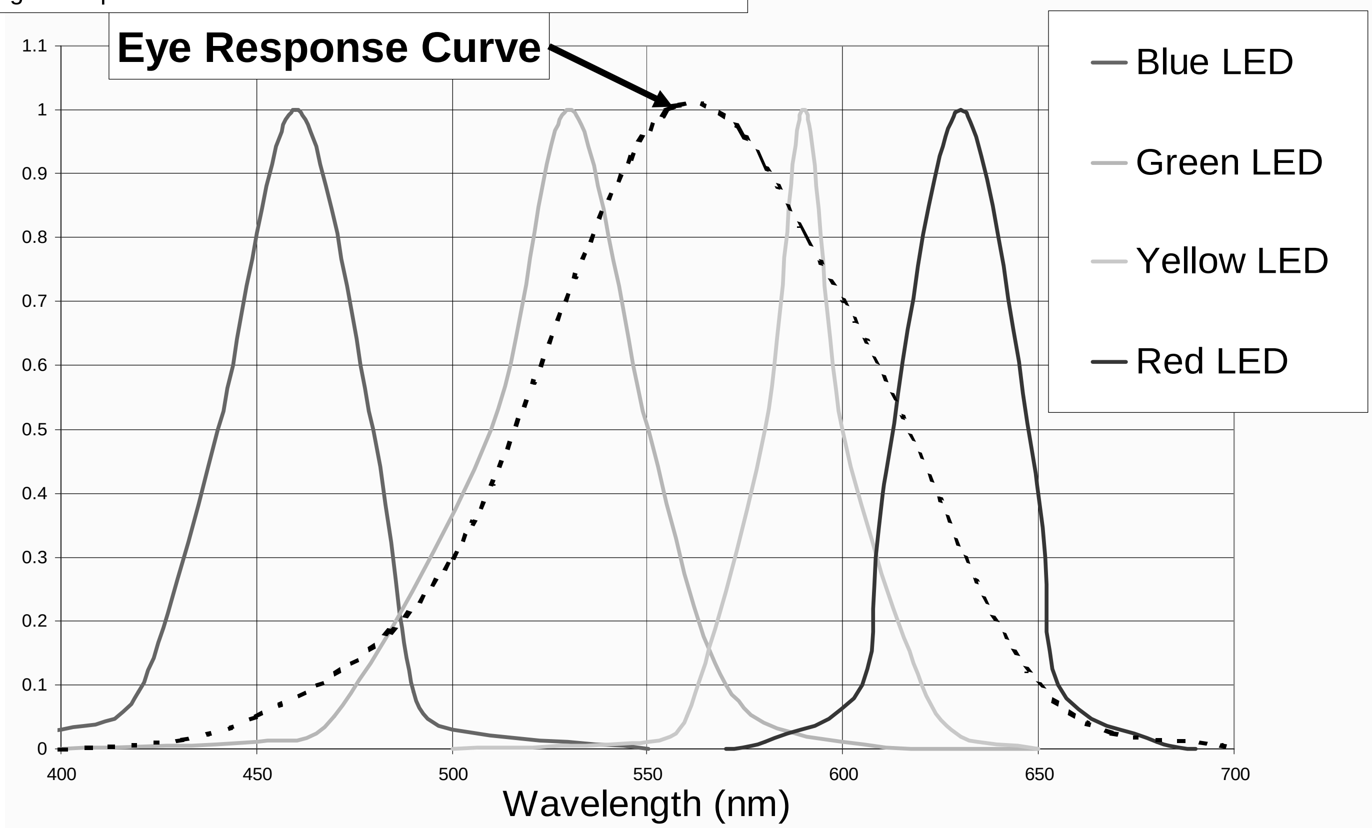
Halogen Spectral Efficiency using Filters

This chart shows the net effect of using filters. The useful energy (called Spectral Efficiency) seen by the human eye for a Tungsten-Halogen lamp with a filter is very low.



LED Spectral Efficiency

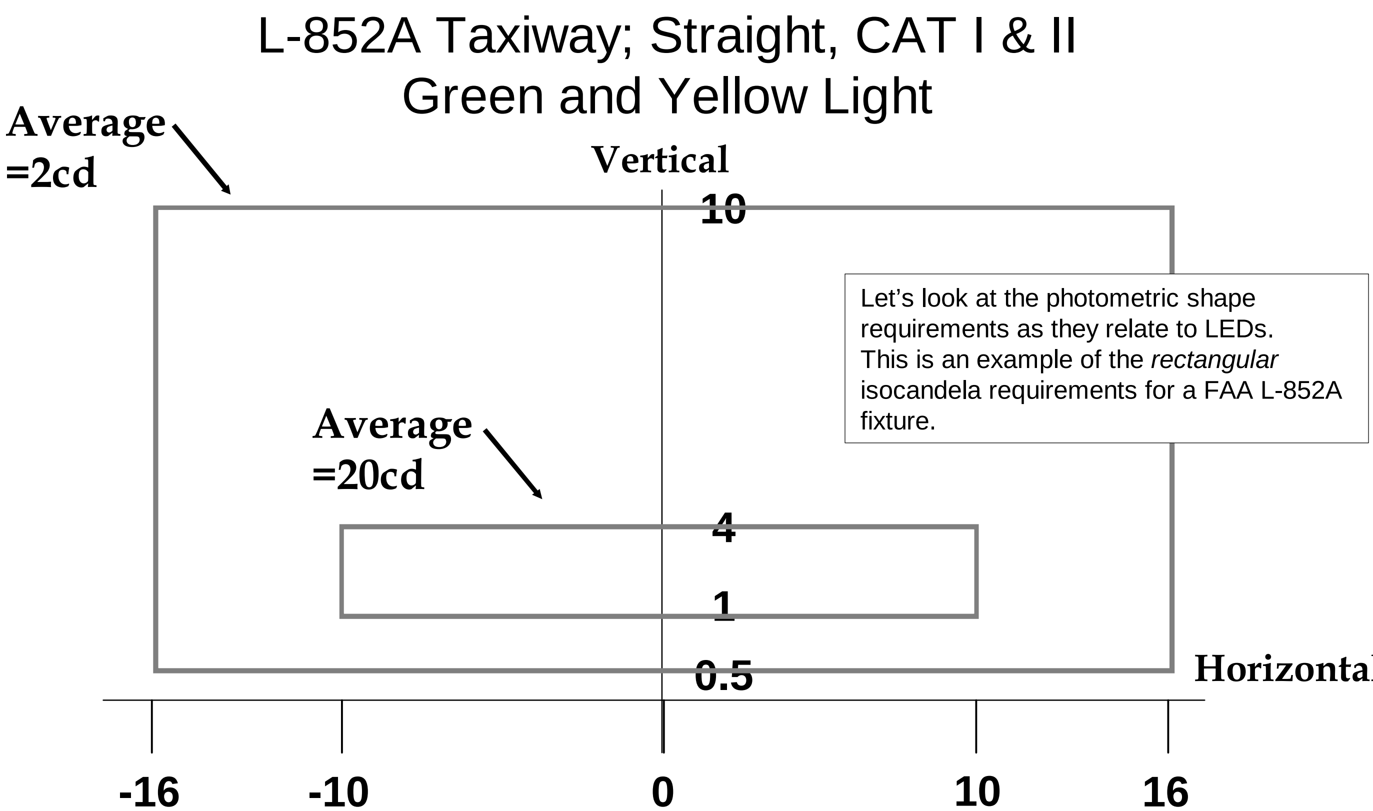
This is a chart comparing the wavelength of light output for LEDs versus the Human Eye Response curve. LEDs directly provide color with no filter so there is no further reduction in useful energy. Therefore, LEDs are inherently more efficient than Tungsten-Halogen lamps.



Color Shift

- Present day airfield lighting fixtures are known to color shift due to the tungsten halogen lamp & filter at:
  - different intensity steps
  - wide angles
- LEDs effectively stay the same color at different intensities and wide angles

FAA L-852A Photometrics



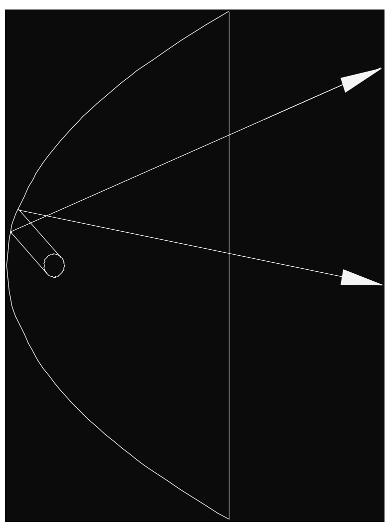
Let’s look at the photometric shape requirements as they relate to LEDs. This is an example of the *rectangular* isocandela requirements for a FAA L-852A fixture.

Halogen Lamp Spatial Efficiency

- A Halogen lamp is essentially a single point source of light
- Beam shaping optics must be used to change an essentially circular pattern of light output to one that is rectangular
- This often results in unavoidable loss of light

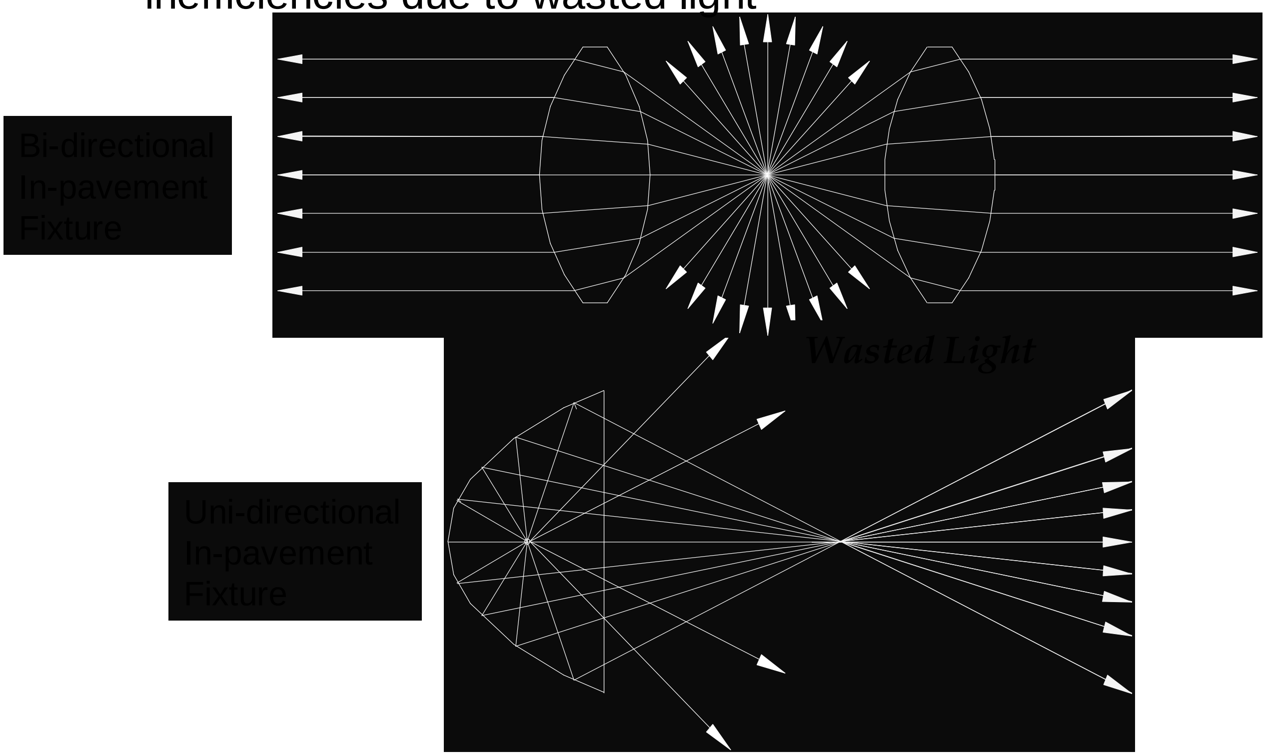
Halogen Lamp Spatial Efficiency

- Effect of lamp geometry and size- some light rays go in undesired directions

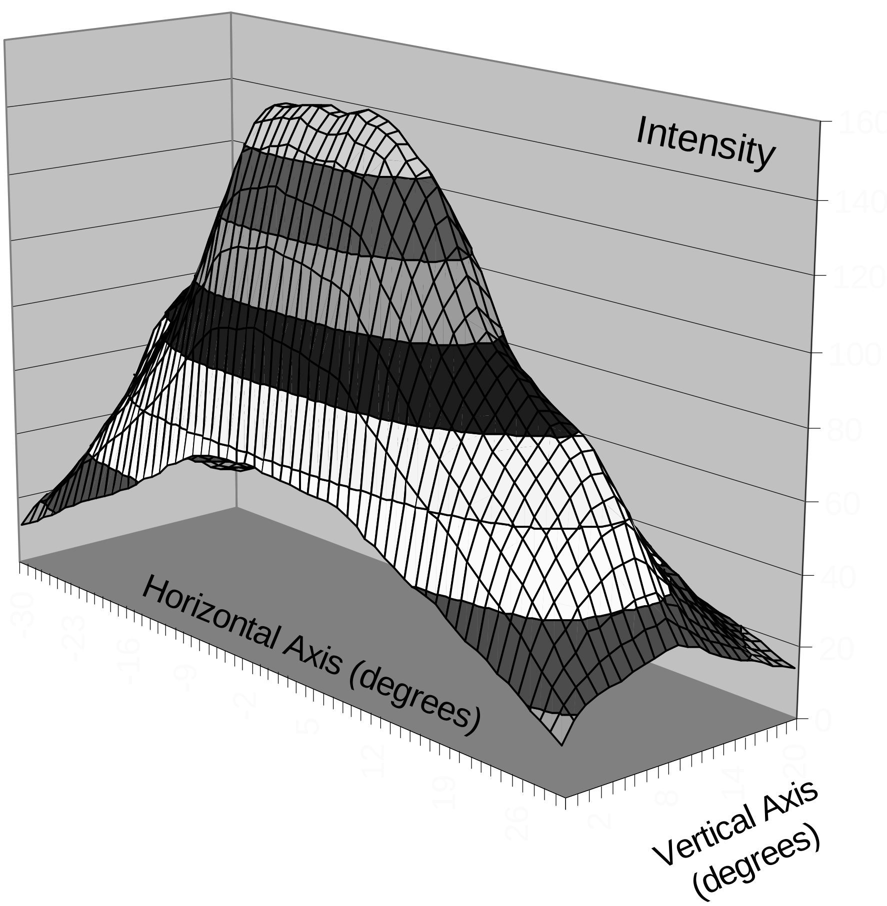


Halogen Lamp Spatial Efficiency

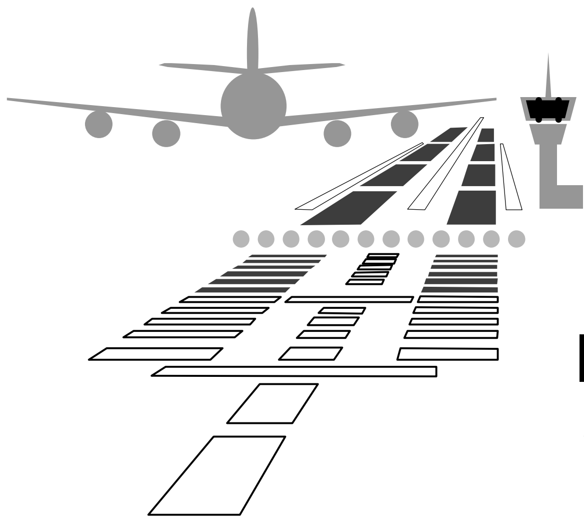
- Relative efficiencies of Unidirectional vs. Bi-directional fixtures
- A bi-directional single source lamp can have additional inefficiencies due to wasted light



LED Spatial Efficiency



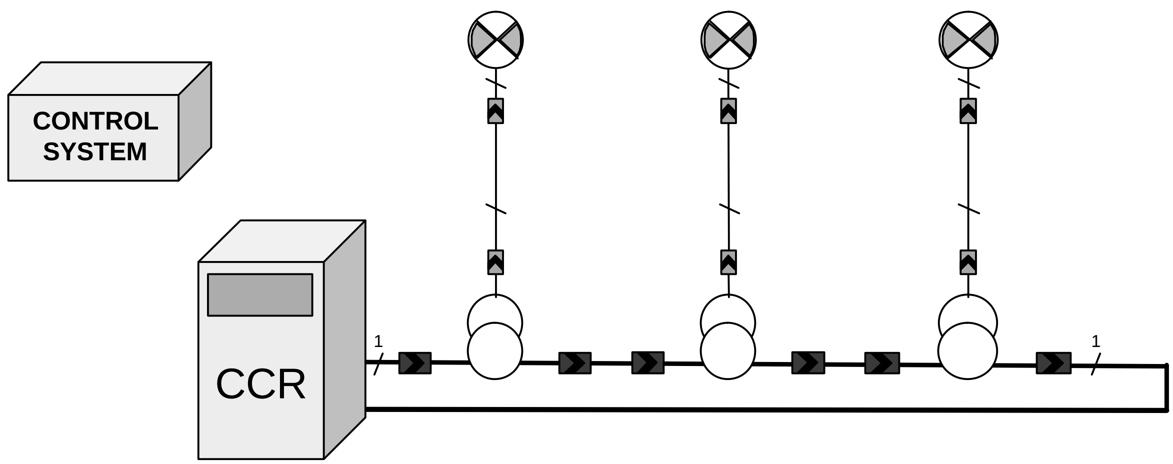
- For CAT I-II-III:
  Lamp wattage
  54 … 125 Watts
  LED wattage (multiple LEDs)
  10 … 20 Watts
- Multiple LED design puts 85% of rays through the window and allows the light output to be tailored to the desired area



Advances in In-pavement Technology

Installation

Installation-Existing Series Circuit

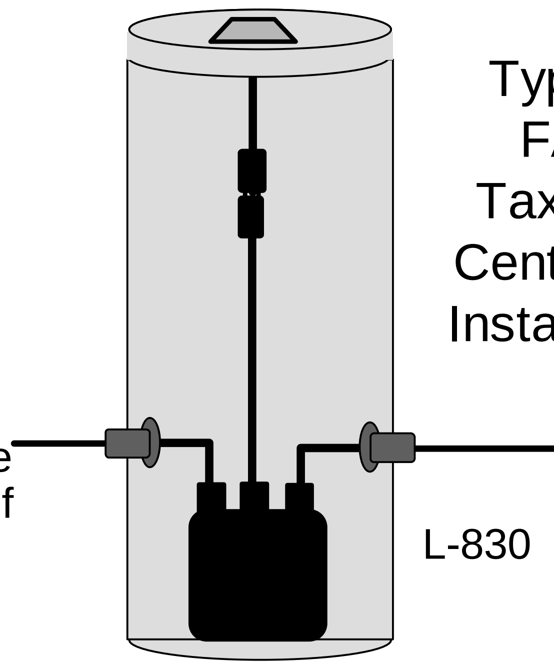


This is an example schematic showing how to add an LED fixture into an existing series circuit. It is simply dropped into place.

Note that new circuits could have all LED fixtures. There would be different application considerations (CCR/transformer size) for an installation of this nature.

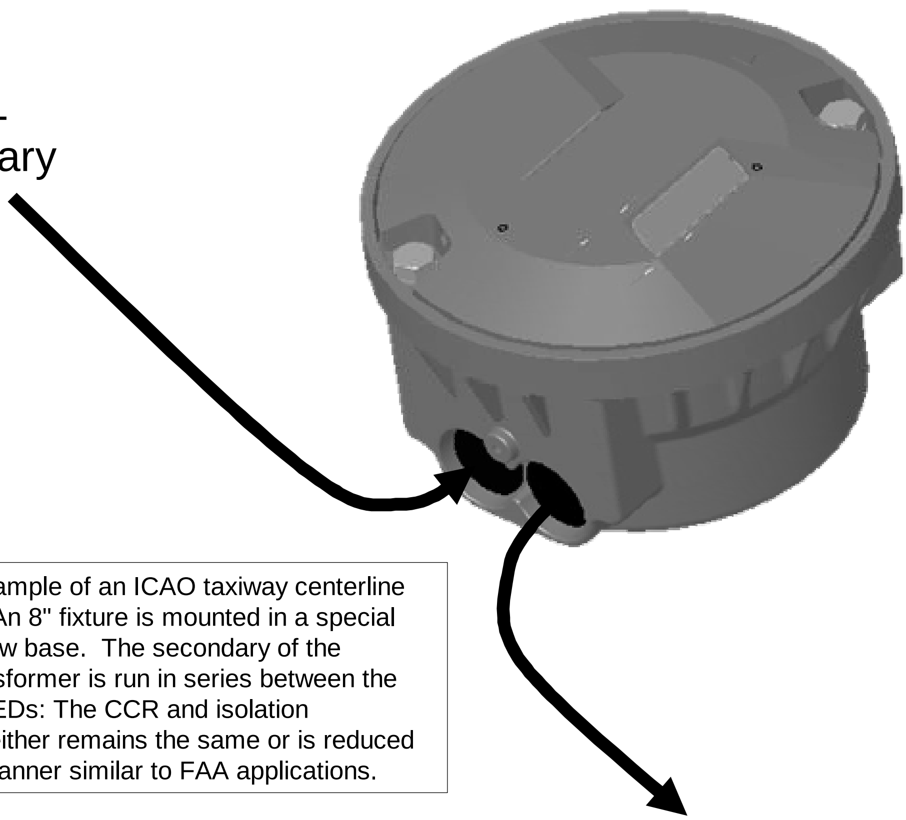
Installation- FAA Applications

- 12"
- Transformer size and effect on the CCR must be considered
- Deep base can (L-868) or
- Adjustable Stainless Steel base can
  - Design guidance for adjustable cans given in Engineering Brief No. 61 available at www.faa.gov/arp/pdf/eb61.pdf



Typical FAA Taxiway Centerline Installation

Installation- ICAO Applications



L-831
Secondary

An
example of
an ICAO
Taxiway
Centerline
Installation

This is an example of an ICAO taxiway centerline installation. An 8" fixture is mounted in a special type of shallow base. The secondary of the isolation transformer is run in series between the lights. For LEDs: The CCR and isolation transformer either remains the same or is reduced in size in a manner similar to FAA applications.

Installation Issues- Effect on CCR

- Substituting LED fixtures on an existing CCR will be possible because load is reduced
  - Will a lower load harm a CCR?
  - What is the effect on efficiency?
- Harm CCR?
  - Specifications require that a CCR must operate from no load to full load
  - CCRs can operate comfortably with lower loads
  - Reduced CCR load also reduces the voltage pressure on cables, accessories

Installation Issues- Effect on CCR

- Effect on efficiency?
  - For SCR CCRs, it is important to have a number of tap adjustments available
  - SCR CCRs typically have, for example, taps in small increments of 10% to 30%
  - For other CCR architectures, it will be important to have good efficiencies at lower load levels

Installation Issues-
Effect on Isolation Transformer

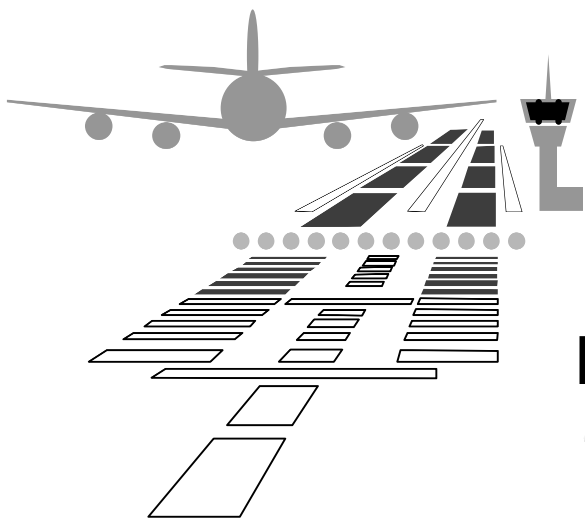
- Underloading a transformer raises two questions:
  - Can the transformer be damaged?
  - What is the effect on current output?

Installation Issues- Effect on Isolation Transformer

- Damage?
  - It is not possible to significantly reduce the life of a transformer with any load, short-circuit, open-circuit, or anywhere in-between
- Underload effect?
  - A transformer is designed to provide the appropriate current (6.6A) at a range of loads
  - If the load is too low, at some point the current may be higher than desired (usually considered to be 6.6A + 1%).

Installation Issues- Effect on Isolation Transformer

- Recommendations:
  - If used on a higher wattage isolation transformer, the LED electronics may need to consider higher current levels
  - New lower wattage transformers need to be developed (20W)



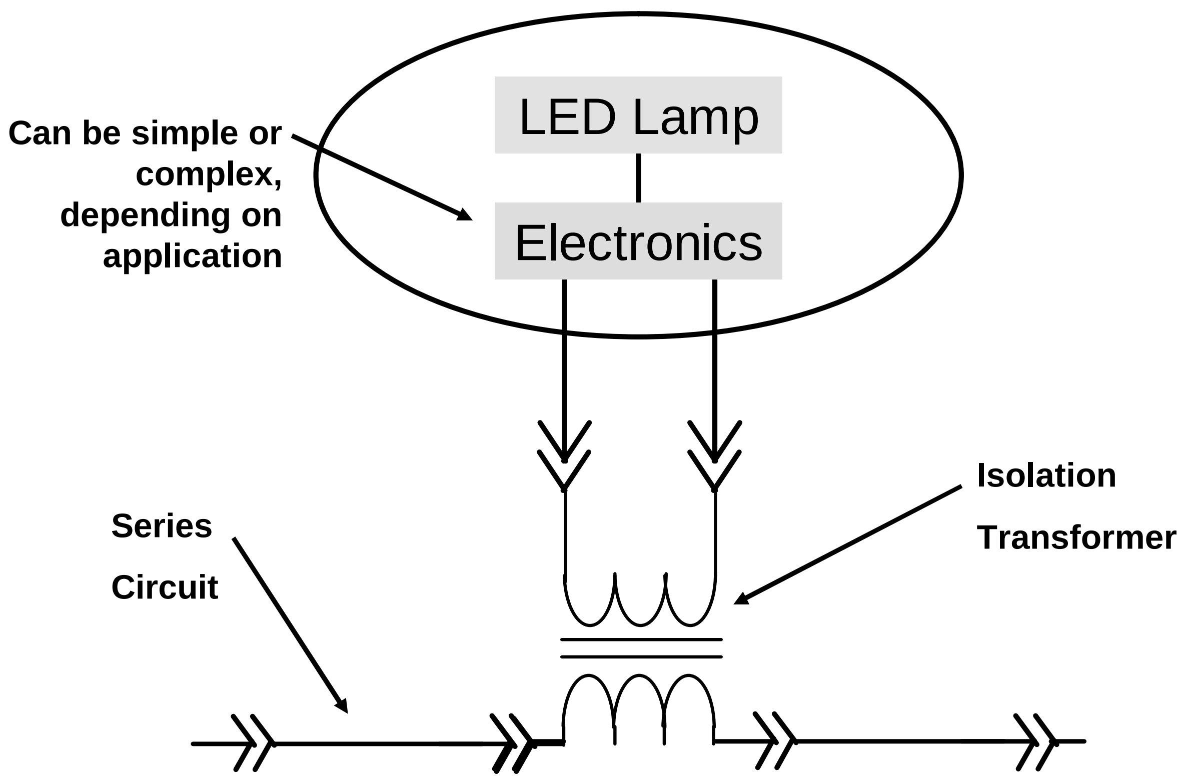
Advances in In-pavement Technology

Electrical Design

Electrical Design

- LEDs are current driven devices
- A regulated DC current must flow through each LED

Typical Block Diagram



Electrical Design- Intensity Ratio

- FAA Specification: "The intensity of an LED fixture…must vary in accordance with characteristic variations of an incandescent lamp…".
  - What is the required curve of light intensity vs. CCR step?
  - Does *incandescent* specifically refer to tungsten halogen lamps?

What are the intensity level requirements?

- Per FAA AC 150/5340-24, par. 5f:

3-Step	Current	Light Level
B100	6.6A	100%
B30	5.5A	30%
B10	4.8A	10%

5-Step	Current	Light Level
B5	6.6A	100%
B4	5.2A	25%
B3	4.1A	5%
B2	3.4A	1.2%
B1	2.8A	0.15%

Electrical Design- Lamp Type

- Definitions
  - Incandescent means to make luminous with heat (hot filament)
  - Tungsten Halogen (Used in many applications)
    - Contains a small quantity of active halogen gas
    - Uses a tungsten filament
    - Lamp body is quartz glass
    - Also called “Tungsten Filament”; “Quartz Halogen” and “Quartz Incandescent”
  - Incandescent Filament (Ex: Sometimes used on L861T)
    - Uses a heated filament
    - Lamp body is optical glass

Electrical Design- Lamp Types Tested

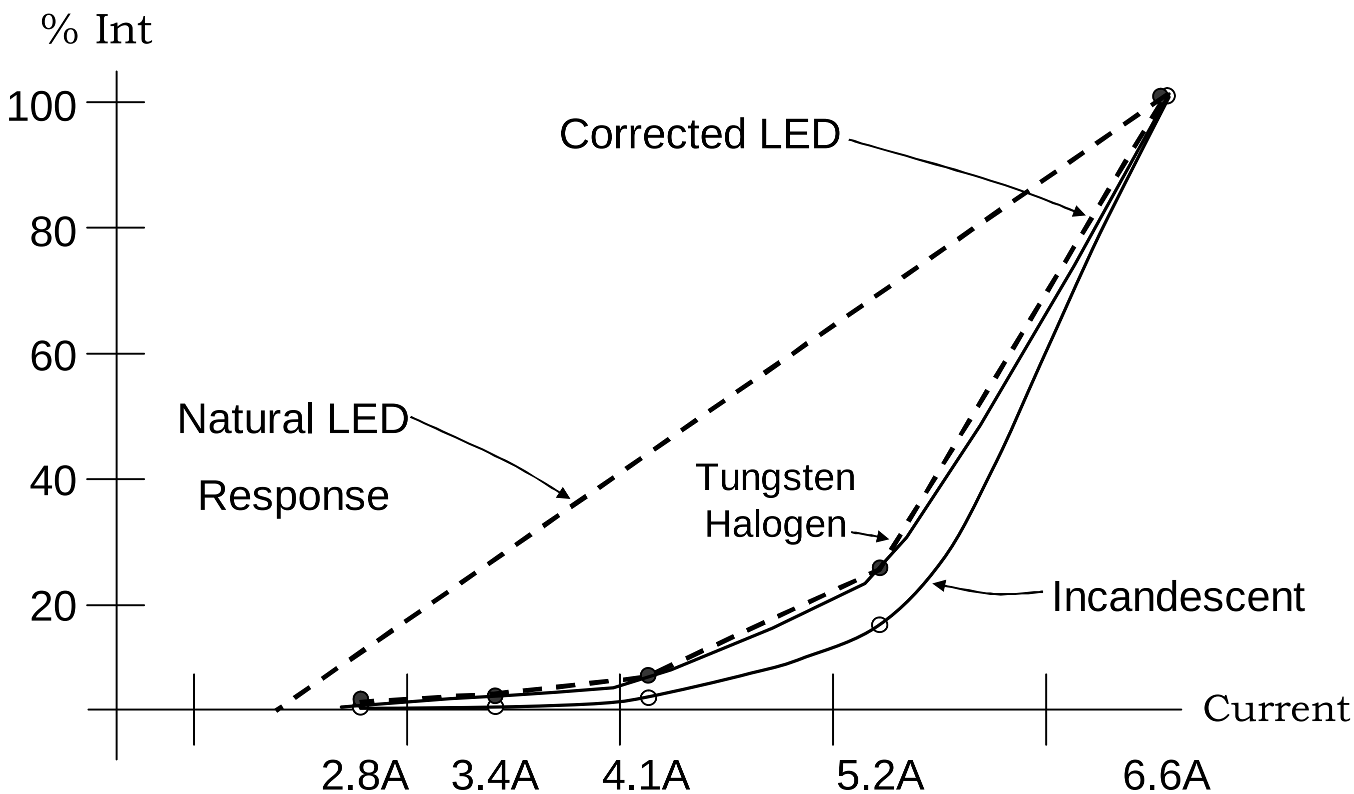
105W MR-16
Tungsten-Halogen

48W MR-16
Tungsten-Halogen

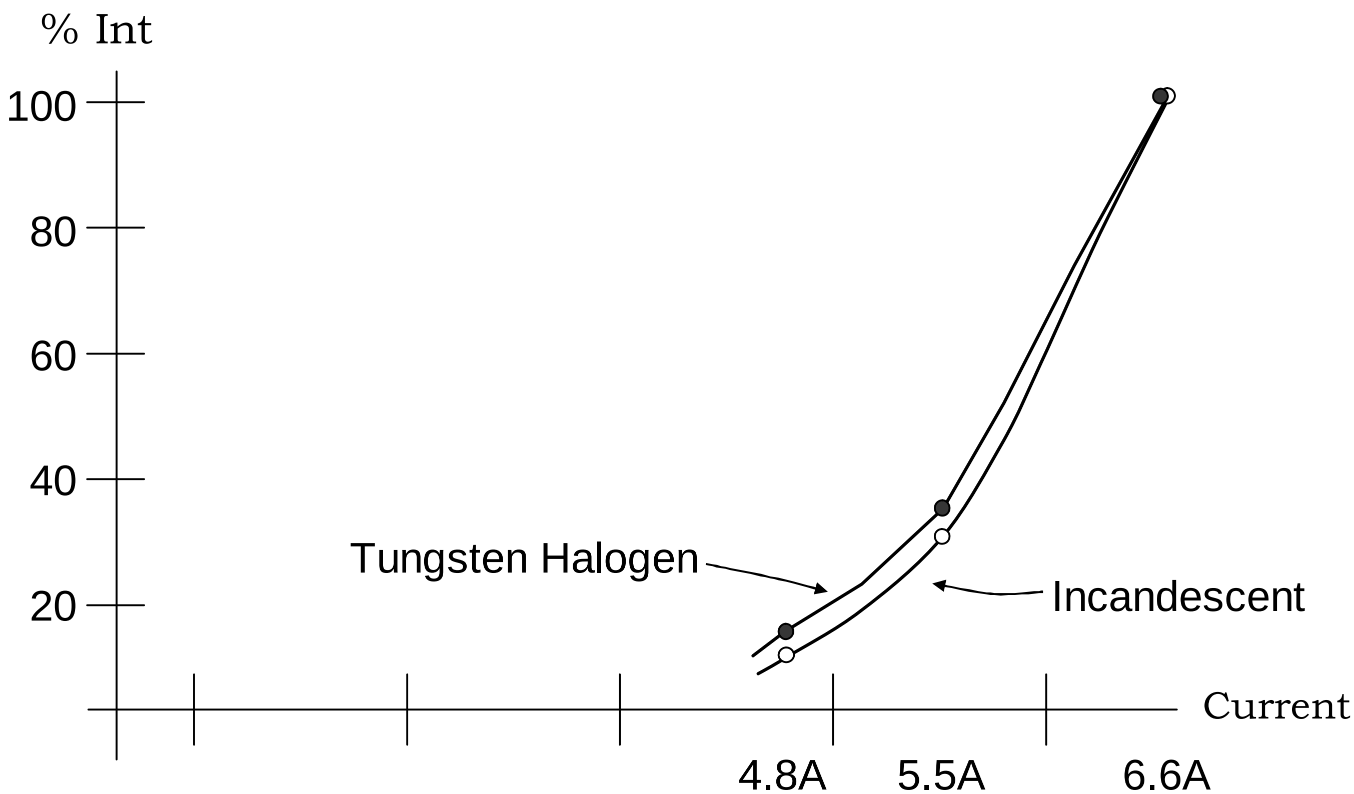
45W T-10
Incandescent
Filament

120W Bi-Pin
Tungsten-Halogen

Comparison with Existing Lamps- 5-step CCR



Comparison with Existing Lamps-3-step CCR



Electrical Design- Tungsten vs. Incandescent

- Conclusions:
  - Light output does not vary with wattage
  - Light output *does* vary between tungsten halogen and incandescent filament
    - Effect of incandescent filament variation more important for elevated LED applications
  - Correlation of expected FAA % light output not consistent and may need to be reviewed
    - Tungsten-Halogen: B30 (36%); B10 (15%)

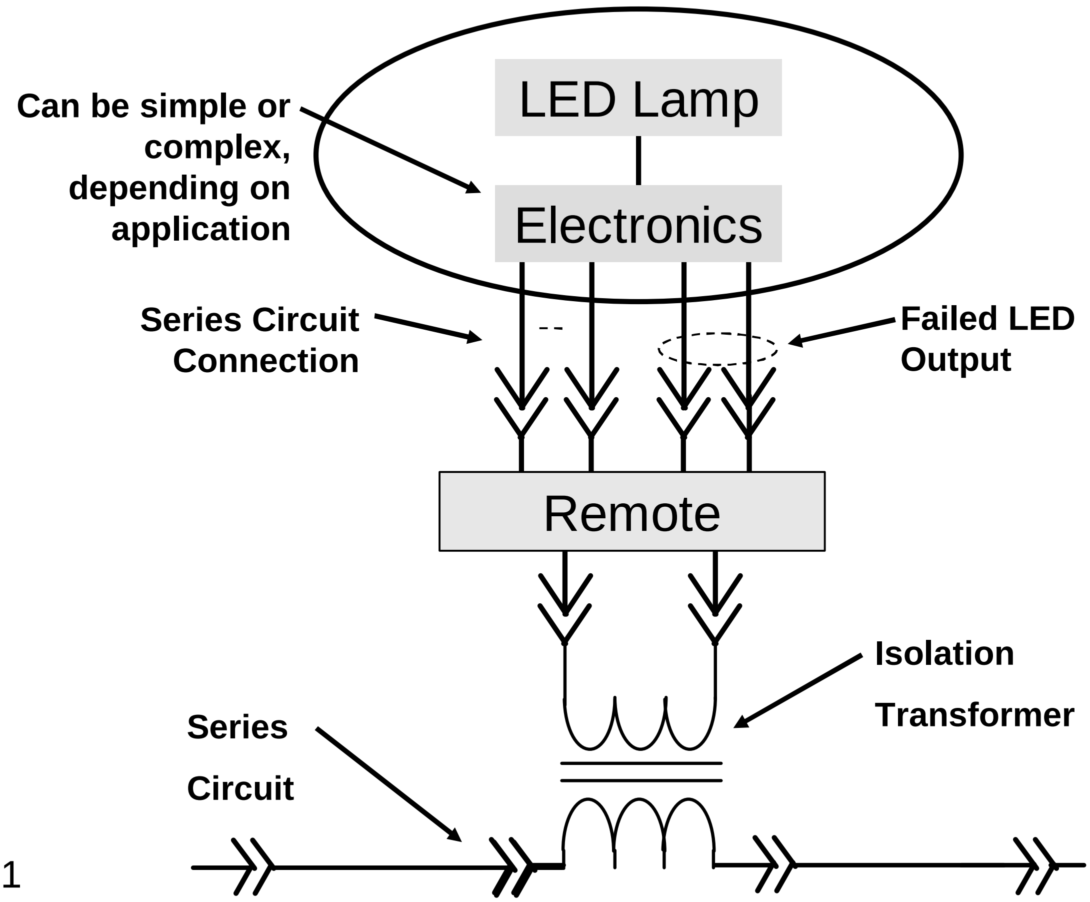
Electrical Design- Monitoring

- FAA Specification: “Design … should discontinue operation if 25% of the LEDs fail.”
- ICAO Specification: The intensity…should never fall to a value less than 50% of the (initial value)...”
- LED fixtures can have internal monitoring circuits or could theoretically be monitored externally
  - External monitoring could be very difficult due to the electronics in fixture

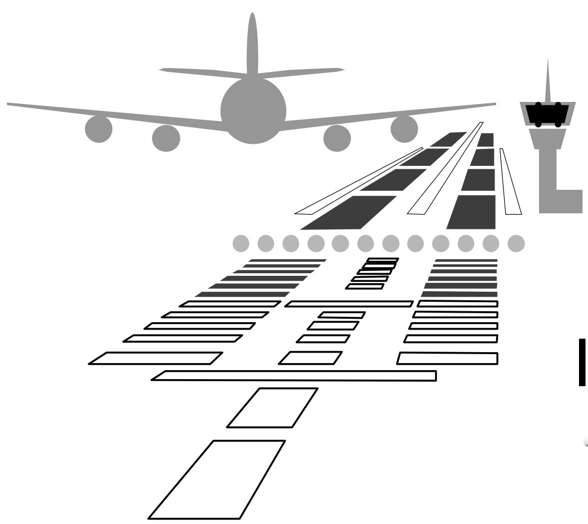
Electrical Design- External Monitoring

- There are numerous ways to design the electronics to accomplish LED current regulation & dimming
  - Resistive circuits
  - Current or voltage regulator circuits
  - Pulse Width Modulation (PWM) circuits
- A failing LED lamp could therefore present different electrical characteristics depending on electronic design and manufacturer
- A standardized means is needed to signal that a fixture has failed

Electrical Design- Internal Monitoring



There are lots of ways to indicate a lamp has failed. One possible way is shown here. A dedicated output could be tied into a Remote control and monitoring device.



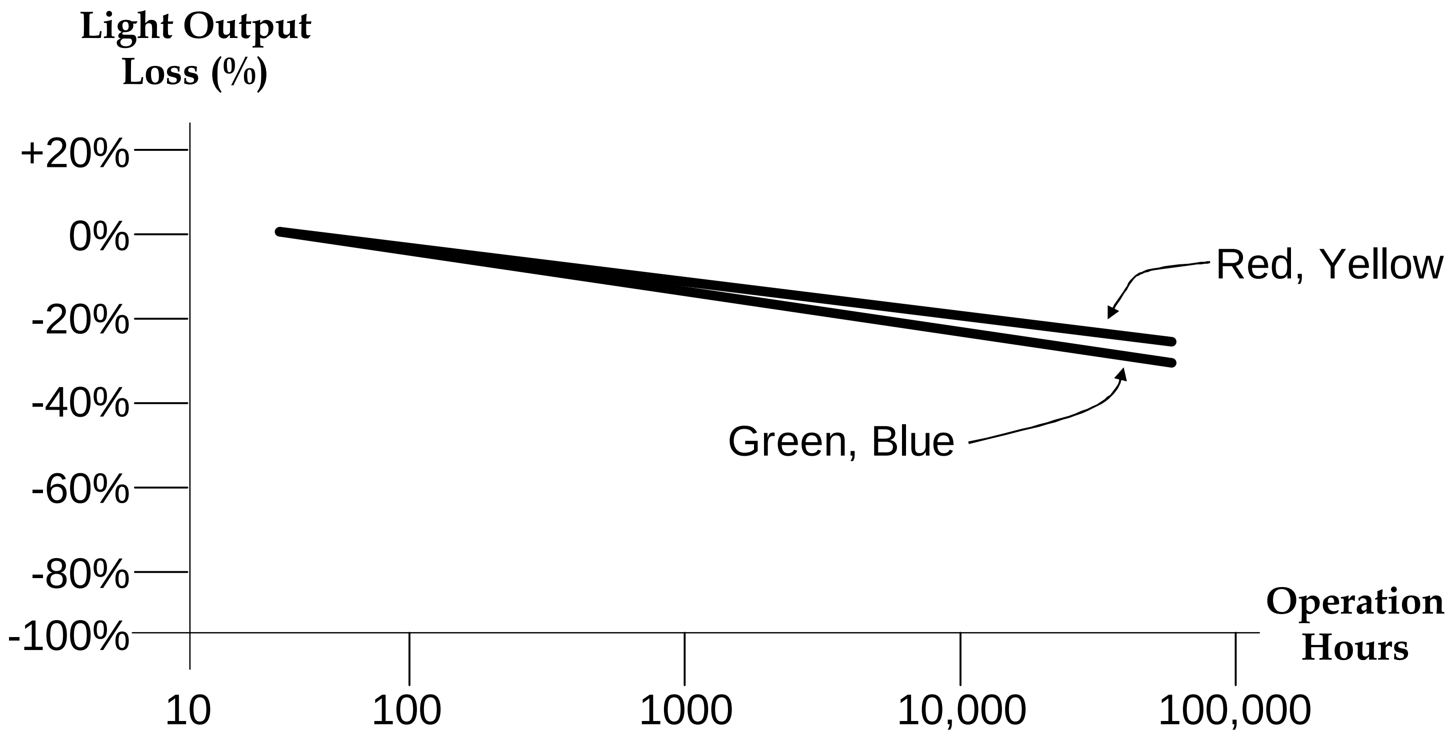
Advances in In-pavement Technology

Technical Issues

Technical Issues- MTBF

- MTBF (Mean Time Between Failure)
  - Single LEDs have better than 100,000 Hrs at full brightness life expectancy
  - Based on a Weibull (bathtub) curve, cluster life expectancy is ~56,000 hours, assuming full brightness level
- At step B10, LEDs may last ten times longer
  - Based on data collected on actual operating steps, expected MTBF of light source with electronic control is around 150,000 Hrs, if operated at lower intensity levels

Technical Issues- Light Output vs. Time



Technical Issues- Light Output vs. Time

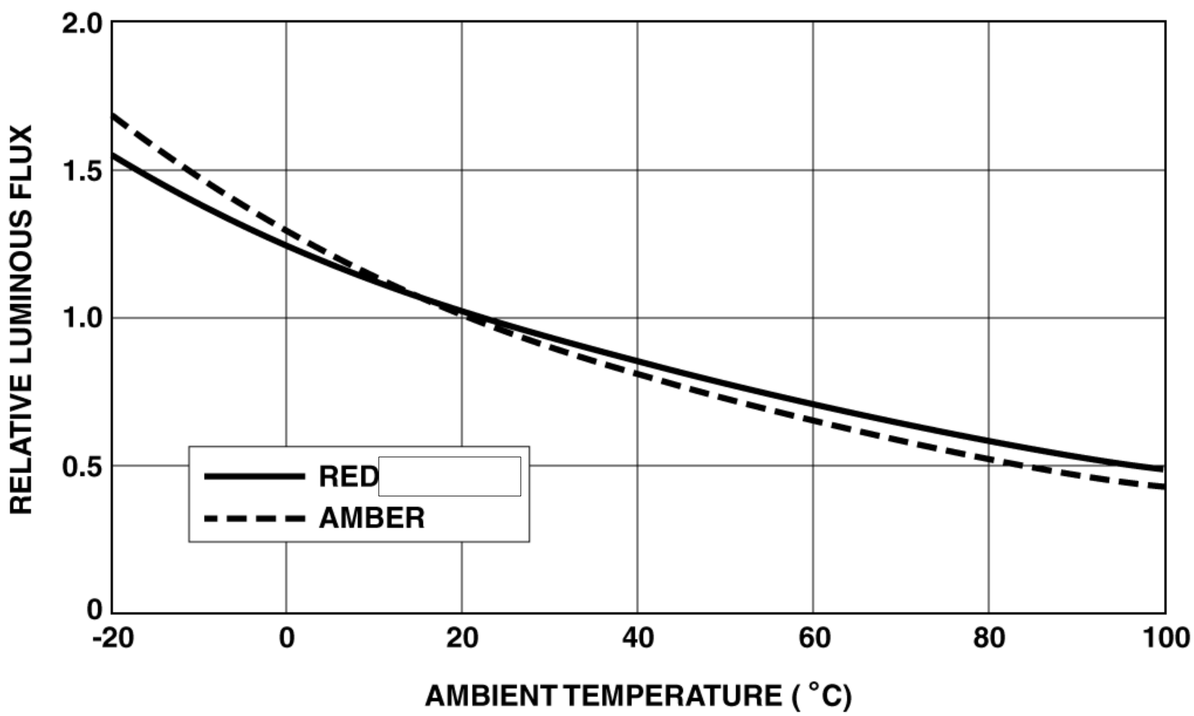
- After ~150,000 hours of operation, failure due to drop in light output may be > MTBF of other components
- In this case, weakest link is not LED; prism and rest of fixture might not last as long as LED
- MTBF of rest of fixture may be more important
  - Reliability of controlling electronics
  - Lightning protection
  - Lifetime of top cover
  - Lifetime of prism

Technical Issues- Temperature

- FAA Specification: “Manufacturers shall insure that the light output of the fixture does not drop more than 30% of the photometric requirements of the applicable AC.”
- LED light does decrease with high temperature, but will recover

Technical Issues- Temperature

- Luminous flux vs. ambient temperature for red & amber AlInGaP LED when operated at constant current

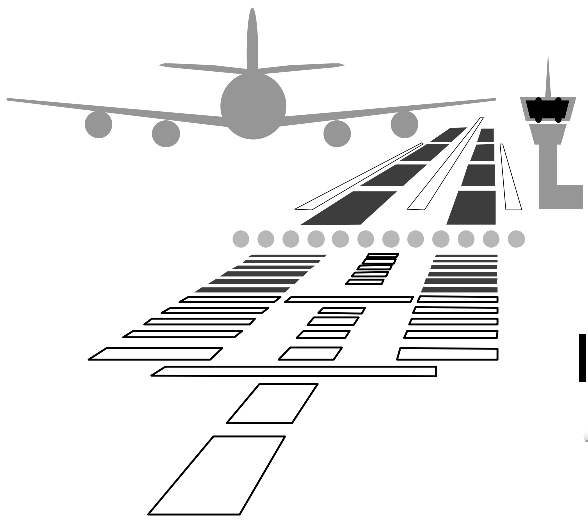


Technical Issues- Temperature

- Loss of light output due to temperature rise must be considered for the fixture under worst-case field installation conditions

Technical Issues- Lightning

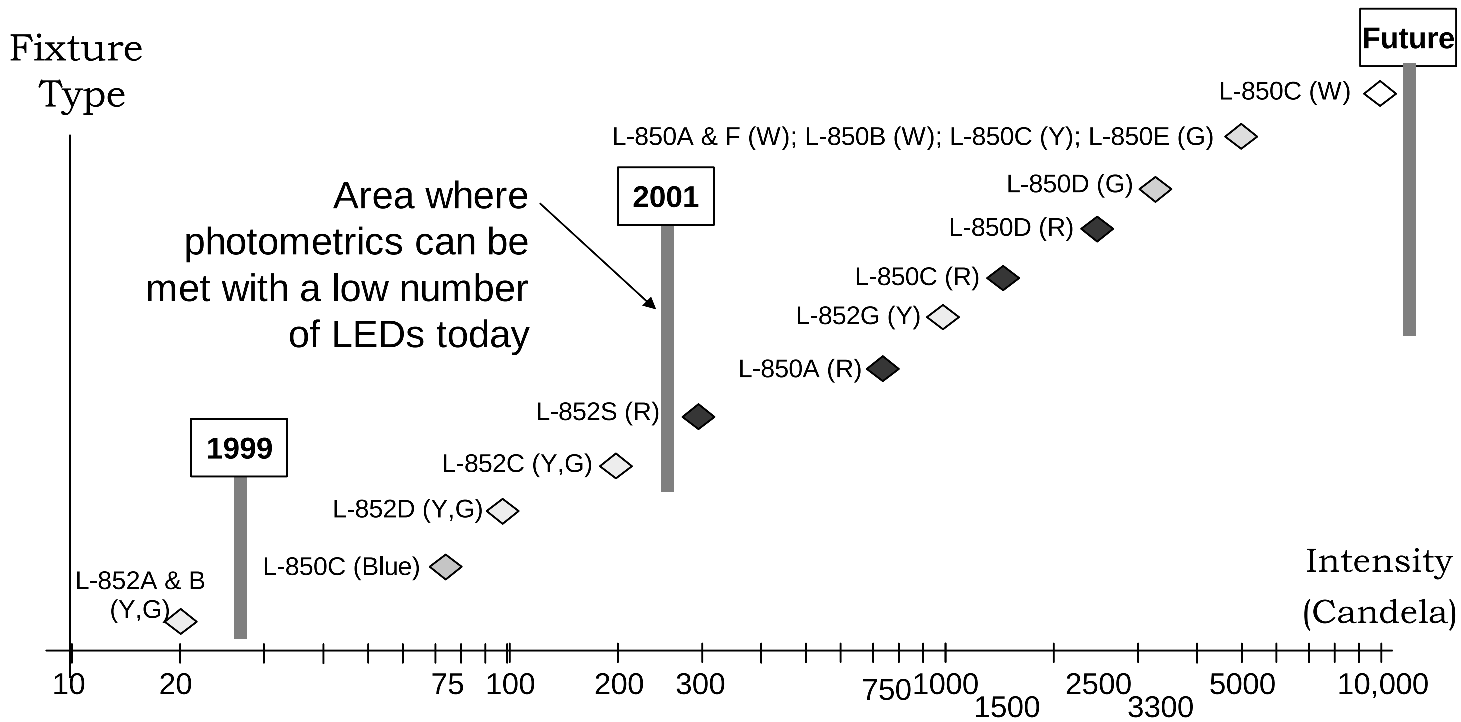
- Lightning protection is a system wide problem, not an airfield component problem
- Lightning protection must be considered by both the by the manufacturer and the A&E (from a overall system perspective)



Advances in In-pavement Technology

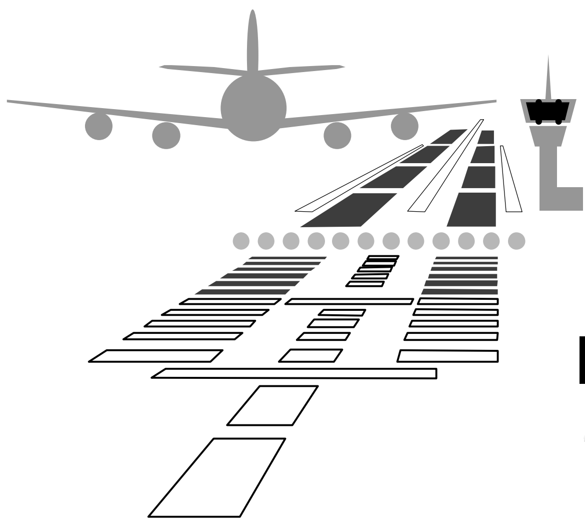
Future

FAA intensity requirements vs. LED technology



Minimum average intensity vs. FAA In-pavement fixture type

Notes: Omni-directional fixtures not included
L-850E is minimum intensity (not average)



Advances in In-pavement Technology

Conclusion

Comparison: Tungsten Halogen – LEDs

• **Unit Cost**	**+**	**~**
•**Life Cycle Cost**	**-**	**+**
• **Maximum Intensity**	**+**	**-**
• **Color Efficiency and Shift**	**-**	**+**
• **Energy Savings**	**-**	**+**
• **Source Life**	**-**	**+**
• **Airfield downtime to replace failed fixture**	**-**	**+**
• **Environment Resistance (Chemical)**	**-**	**+**
• **Mechanical Resistance (Vibration)**	**-**	**+**
• **New vs. Mature Product**	**+**	**-**
• **Types of Spare Parts**	**-**	**+**
• **Auxiliary Costs (Xformer size/CCR power)**	**-**	**+**

Conclusion

- LEDs are bright enough to allow them to be applied to in-pavement lighting
- LEDs will be commonplace in the future
- Application issues should be carefully considered by A&Es
  - Ex.: loading of CCRs; size of transformer, etc.
- LEDs are an optimal choice for Life Cycle Cost improvement